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Acoustic Characterization of an Aluminum Plate with Corrugated Surface

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Abstract

In this paper, the propagation of Lamb waves in an aluminum plate with a controlled roughness is studied. The roughness is located in a limited zone of the plate. The power spectral density (PSD) of the roughness exhibits three main peaks. Theoretically, a phonon relation can be written, linking the wavenumber of an incident Lamb mode, the wavenumber of a reflected converted Lamb mode and the phonon related to a peak of the DSP. Experimentally, an incident Lamb mode is excited on the flat side and its interaction with the roughness is studied. Reflected converted waves and the transmission of the incident Lamb mode are observed. Experimental results show the link between the main spatial frequencies included in the roughness and the wavenumber of the converted modes, as predicted theoretically.

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1. Introduction

Many studies have done on the interaction of the guided waves and a roughness (Chimenti and Lobkis (1997,1998), Leduc et al. (2005), Potel et al. (2008)). They have shown the importance of the spatial periodicities. In papers dealing with grating composed by triangular grooves (Leduc et al. (2006, 2009), Morvan et al. (2007)), it

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has been shown that a Lamb wave incident on a gives rise to reflected converted modes at particular frequencies. This paper is the next step to a comprehension for a much complicated situation where the roughness is not related to a grating. The investigation deals with an aluminum plate with a controlled roughness. In the first part, the geometry of the sample is presented. Then, the phonon relation is recalled. Finally, after a description of the experimental set up, results are presented.

2. Geometry of the sample

The sample is an aluminum plate with a roughness located in a limited zone. Figure (1a) gives us the profile at the surface of the roughness part. It is made by a surface profiler with a stylus of 2.5 µm and a precision of 60 000 points for a 4cm length. Then to obtain the spatial wavelength present on the sample, the power spectral density (PSD) is realized. It is obtained from the Fourier transform of the autocovariance function of the surface profile (Stoica and Moses (1997), Elson and Bennett (1995)). Figure (1b) gives the evolution of the PSD versus the spatial period. Despite the complicated roughness (see fig (1)), we obtain three main peeks which are located at $\Lambda_{1,2,3}$= 2, 3.7 and 5 mm.

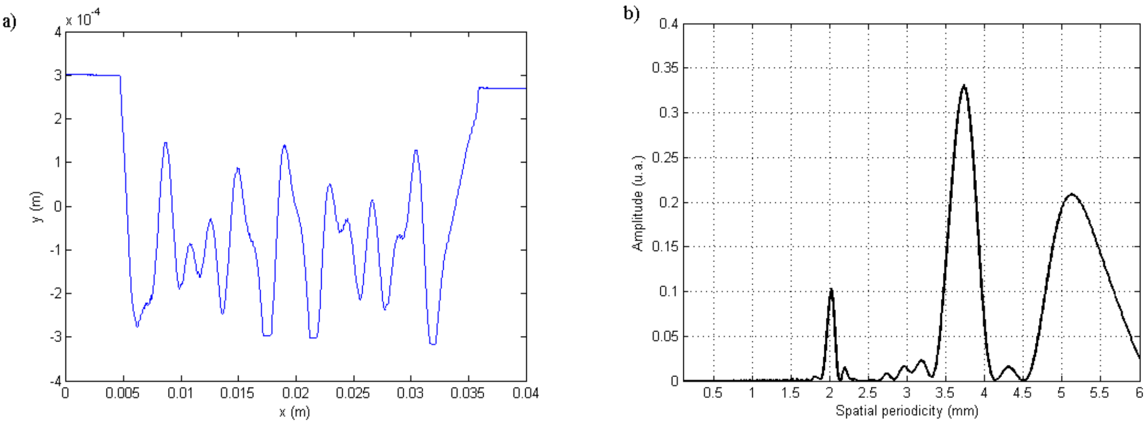

Fig. 1. (a)Surface profile and (b) Power spectral density (PSD) of the studied aluminum plate

3. The phonon relation

The previous studies have shown link between the incident and the reflected converted waves was a phonon relation. The process can be described as a collision of phonons. The law of conservation of phonon momentum can be written:

$$\vec{p}_{IM} = \vec{p}_{PH} + \vec{p}_{CM} \quad (1)$$

where p_{IM} is the momentum related to the incident mode, p_{PH} to the phonon and p_{CM} to the converted mode.
The converted mode propagates in this case in the opposite direction of the incident mode. The phonon propagates under the roughness in the direction of propagation of the incident wave. This implies a relation between wavenumbers:

$$k_{IM} = n\frac{2\pi}{\Lambda} - k_{CM} \quad (2)$$

where Λ is one of the spatial wavelength present in the DSP of the profile. It has to be noticed that the previous relations hold for particular frequencies.

4. Experimental set up

A generator delivers a burst to a piezocomposite transducer used with a plexiglas wedge. A water base coupling gel is used to improve the transmission of the ultrasonic waves at each interface (between the transducer and the wedge, and between the wedge and the aluminum plate). The central frequency of the transducer is 1MHz and the wedge has an angle of 60°. The burst is composed of 10 periods at a frequency of 755 kHz with an amplitude of 10V peak to peak.. The wave propagates 45 mm before reaching the roughness and a laser vibrometer is used for the detection. The answer is recorded along a distance of 45 mm with a translation step of 0.1mm. For each position of the vibrometer, an average of 300 shots is performed and a signal of 100 µs long and a time step of 5 ns is stored. Finally an (x,t) image is obtained from which the 2D FFT is performed to characterize the waves in the dual space.

5. Results

The positive components of wave number which represent the incident waves (Figure 2), whereas the negative components correspond to converted/reflected waves (Figure 3). The theoretical dispersion curves are superimposed on the experimental data. Figure 2 shows that two modes are excited: S0 and A1. The wave number of the converted reflected modes are given by the Figure 3 (a) and (b) and written in the Table 1. The phonon relation is applied and for each reflected converted wave, one of the spatial wavelength is found with n=1 or n=2. Thus, building on the experimental results, we verify equation (2). For example, using the wave number of the incident modek_{S0} = 1577 m^{-1}, and the wave number of the reflected converted wave k_{CM} = 1530 m^{-1}, we find Λ=2.02 mm for n=1 which is the value of Λ_1. The same calculation can be done for each reflected converted wave number for n=1 or n=2. Results are summarized in the Table 1. In spite of the rather complicated shape of the roughness (see Fig. 1a) the interaction between the incident mode and the roughness can be easily understood in the dual space.

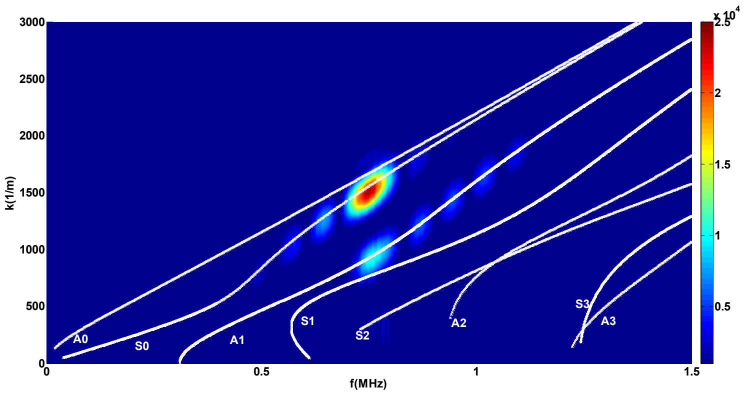

Fig.2. Incident signal in the dual space (k,f) with the theoretical dispersion curves superimposed

Table 1 : Results of phonon relation

Incident wave	Name	S0				A1		
	Wave number	1577				935		
Reflected/converted wave	Wave number	-1790	-1545	950	-190	-1545	-810	-300
Spatial periodicity	n=1	-	2.01	-	3.59	-	3.6	5.09
	n=2	3.73	-	4.97	-	5.06	-	-

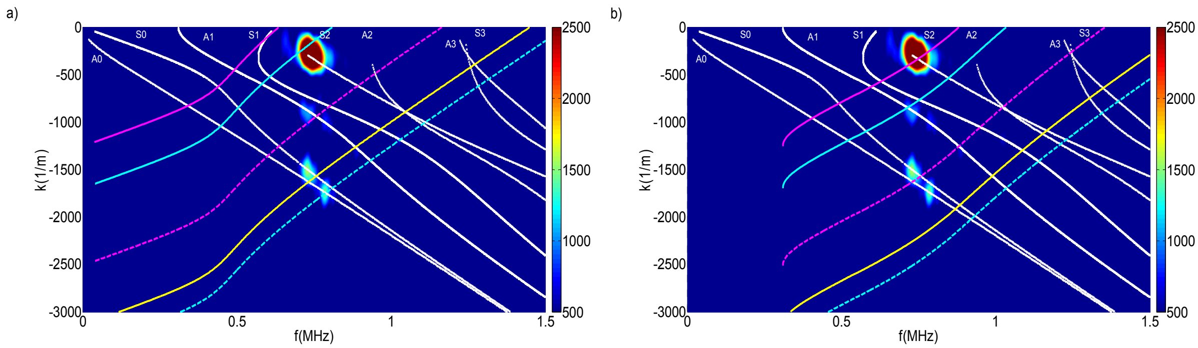

Fig.3. Reflected / converted waves in the dual space (k,f) with phonon curves for the incident mode S0 (a) and A1(b).The pink represent the wavelength 5 mm, the cyan 3.7 mm and the yellow 2 mm. The lines are phonon curves for n=1 and the dash for n=2.

6. Conclusion

The acoustic characterization of corrugated plates can be realized by Lamb waves in the dual space. The PSD of the surface profile gives the spatial wavelengths present on the surface. After collecting the values of the wavenumber of the reflected converted modes in the dual space, the phonon relation allows us to understand the origin of the retro converted modes. Therefore the interaction between the incident Lamb wave and the roughness can be easily understood in the dual space.

References

Chimenti, D. E., &Lobkis, O. I. (1998). Effect of rough surfaces on guided waves in plates.In *Review of Progress in Quantitative Nondestructive Evaluation* (pp. 129-136).Springer US.

Lobkis, O. I., &Chimenti, D. E. (1997). Elastic guided waves in plates with surface roughness. I. Model calculation. *The Journal of the Acoustical Society of America*, *102*(1), 143-149.

Lobkis, O. I., &Chimenti, D. E. (1997). Elastic guided waves in plates with surface roughness. II. Experiments. *The Journal of the Acoustical Society of America*, *102*(1), 150-159.

Leduc, D., Hladky, A. C., Morvan, B., Izbicki, J. L., &Pareige, P. (2005). Propagation of Lamb waves in a plate with a periodic grating: interpretation by phonon. *The Journal of the Acoustical Society of America*, *118*(4), 2234-2239.

Leduc, D., Morvan, B., Hladky, A. C., Pareige, P., &Izbicki, J. L. (2006). Lamb wave propagation in a plate with a grooved surface with several spatial periodicities. *Ultrasonics*, *44*, e1359-e1363.

Morvan, B., Hladky-Hennion, A. C., Leduc, D., &Izbicki, J. L. (2007). Ultrasonic guided waves on a periodical grating: Coupled modes in the first Brillouin zone. Journal of applied physics, 101(11), 114906.

Potel, C., Leduc, D., Morvan, B., Depollier, C., Hladky-Hennion, A. C., Izbicki, J. L., ...&Bruneau, M. (2008). Lamb wave attenuation in a rough plate. II. Analytical and numerical results in a fluid plate. *Journal of Applied Physics*,*104*(7), 074909.

Leduc, D., Morvan, B., Hladky, A. C., &Izbicki, J. L. (2009). Interaction of Lamb waves with a grating composed of two spatial periodicities: Study in dual space. *NDT & E International*, *42*(6), 513-517.

Stoica, P., & Moses, R. L. (1997). Introduction to spectral analysis (Vol. 1). Upper Saddle River: Prentice hall.

Elson, J. M., & Bennett, J. M. (1995). Calculation of the power spectral density from surface profile data.Applied Optics, 34(1), 201-208.